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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO. (If known, see 37 CFR 1.5)	
				09/830825	
INTERNATIONAL APPLICATION NO. PCT/DE00/02879		INTERNATIONAL FILING DATE 23 August 2000 (23.08.00)		PRIORITY DATE CLAIMED: 28 August 1999 (28.08.99)	
TITLE OF INVENTION SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION IN GAS MIXTURES AND METHOD FOR ITS MANUFACTURE					
APPLICANT(S) FOR DO/EO/US Heiner SCHEER, Udo JAUERNIG, Hans-Joerg RENZ, Lothar DIEHL, Dieter LINDAUER, and Juergen KARLE					
Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information.					
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p><input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.</p> <p><input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).</p> <p><input type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</p> <p><input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))</p> <p>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</p> <p>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</p> <p>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input checked="" type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).</p> <p>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>Items 11. to 16. below concern other document(s) or information included:</p> <p>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.</p> <p>14. <input checked="" type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input checked="" type="checkbox"/> Other items or information: International Search Report (translated), and PCT/RO/101.</p>					

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- The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):Search Report has been prepared by the EUROPEAN PATENT OFFICE or
JPO \$860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) \$690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but
international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$710.00Neither international preliminary examination fee (37 CFR 1.482) nor international search
fee (37 CFR 1.445(a)(2)) paid to USPTO \$1,000.00International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims
satisfied provisions of PCT Article 33(2)-(4) \$100.00

CALCULATIONS | PTO USE ONLY

JC08 Rec'd PCT/PTO 30 APR 2001

ENTER APPROPRIATE BASIC FEE AMOUNT = \$ 860

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months
from the earliest claimed priority date (37 CFR 1.492(e)). \$

Claims	Number Filed	Number Extra	Rate
Total Claims	24 - 20 =	4	X \$18.00
Independent Claims	2 - 3 =	0	X \$80.00
Multiple dependent claim(s) (if applicable)			+ \$270.00

\$ 72

\$ 0

\$

TOTAL OF ABOVE CALCULATIONS = \$ 932

Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must
also be filed. (Note 37 CFR 1.9, 1.27, 1.28). \$

SUBTOTAL = \$ 932

Processing fee of \$130.00 for furnishing the English translation later the ☐ 20 ☐ 30
months from the earliest claimed priority date (37 CFR 1.492(f)). + \$

TOTAL NATIONAL FEE = \$ 932

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property + \$

TOTAL FEES ENCLOSED = \$ 932

Amount to be:	
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- a.
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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be
filed and granted to restore the application to pending status.SEND ALL CORRESPONDENCE TO:
Kenyon & Kenyon
One Broadway
New York, New York 10004

SIGNATURE

Richard L. Mayer, Reg. No. 22,490

NAME

DATE



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PATENT TRADEMARK OFFICE

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JCO8 Rec'd PCT/PTO 30 APR 2007
[10191/1810]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s) : SCHEER, Heiner et al.
Serial No. : To Be Assigned
Filed : Herewith
For : SENSOR ELEMENT FOR DETERMINING THE OXYGEN
CONCENTRATION IN GAS MIXTURES AND METHOD FOR
ITS MANUFACTURE
Art Unit : To Be Assigned
Examiner : To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

**PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT**

SIR:

Please amend the above-identified application before examination, as set forth below.

IN THE TITLE:

Please replace the title with the following new title:

-- SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION IN
GAS MIXTURES AND METHOD FOR ITS MANUFACTURE --.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. A marked-up copy of the specification showing added and deleted sections is also provided herewith. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

Please cancel claims 1-23, without prejudice. Please add new claims 24-47 as follows:

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24. (New) A sensor element for determining a concentration of gas components in gas mixtures, comprising:

- a measuring gas chamber;
- at least one pump cell which pumps oxygen at least one of into and out of the measuring gas chamber;
- at least one concentration cell including at least one reference electrode and a measuring electrode, the at least one reference electrode interacting with the measuring electrode, the measuring gas chamber and the reference gas channel being situated in a same layer plane;
- a reference gas channel, the at least one reference electrode being arranged in the reference gas channel, the reference gas channel providing the at least one reference electrode contact with a reference gas intake; and
- a partition arranged between the measuring gas chamber and the reference gas channel, the partition having a measuring-gas side and a reference-gas side, the partition including a base, the base being a ceramic paste applied to an adjacent solid electrolyte foil.

25. (New) The sensor element as recited in claim 24, wherein the sensor element is configured to determine an oxygen concentration in exhaust gases of internal combustion engines.

26. (New) The sensor element as recited in claim 24, wherein a geometry of the partition is adapted to a reference-gas-side boundary of the measuring electrode.

27. (New) The sensor element as recited in claim 24, wherein the measuring electrode has an annular design and is formed in the measuring gas chamber, and the partition is a segment of a circular ring.

28. (New) The sensor element as recited in claim 24, wherein the reference electrode has a boundary on a side of the measuring gas chamber, the boundary being adapted to a shape of the reference-gas side of the partition.

29. (New) The sensor element as recited in 24, wherein the reference electrode has a tapered surface, the surface having a first edge toward an end of the reference gas channel nearest the measuring gas chamber and a second edge toward an end of the reference gas channel nearest the

reference gas intake, the surface being tapered from the first edge to the second edge, the reference electrode surface approaching a center point of the measuring electrode.

30. (New) The sensor element as recited in claim 24, wherein at least a section of at least one of the reference gas channel and the reference electrode is led around the measuring gas chamber.

31. (New) The sensor element as recited in claim 24, wherein the pump cell includes an inner pump electrode, the pump electrode being arranged in the measuring gas chamber opposite to the measuring electrode.

32. (New) The sensor element as recited in claim 24, wherein the measuring electrode is situated in the measuring gas chamber and forms an inner pump electrode of the pump cell.

33. (New) The sensor element as recited in claim 24, further comprising:
a large surface facing the gas mixture, the large surface having at least one opening; and
wherein the measuring gas chamber is coupled to at least one of the at least one opening on the large surface of the sensor element facing the gas mixture, the opening being substantially normal to an upper surface of the sensor element, the opening allowing the gas mixture to enter into the measuring gas chamber.

34. (New) The sensor element as recited in claim 33, wherein the measuring gas chamber is circular, a center point of the circle lying on a center line of one of the at least one opening.

35. (New) The sensor element as recited in claim 31, further comprising an annular diffusion barrier, the diffusion barrier arranged in front of the measuring electrode and the inner pump electrode in a diffusion direction of the gas mixture, the measuring electrode and the inner pump electrode being annular in design.

36. (New) The sensor element as recited in claim 33, wherein the reference electrode is situated on a side of the reference gas channel nearest the large surface of the sensor element exposed to the gas mixture.

37. (New) The sensor element as recited in claim 24, wherein two diametrically opposed reference electrodes are situated in the reference gas channel.

38. (New) The sensor element as recited in claim 24, wherein the measuring electrode includes a portion situated outside of the measuring gas chamber.

39. (New) The sensor element as recited in claim 24, wherein at least one of the at least one reference electrodes includes a portion situated outside of the reference gas channel (15).

40. (New) The sensor element as recited in claim 24, wherein the reference gas channel is at least partially filled in with a porous ceramic material.

41. (New) The sensor element as recited in claim 24, further comprising:
a first solid electrolyte foil exposed to the gas mixture; and
a solid electrolyte layer containing the measuring gas chamber and the reference gas channel;
wherein the solid electrolyte layer is directly deposited on the solid electrolyte foil.

42. (New) The sensor element as recited in claim 41, further comprising:
a second solid electrolyte foil;
a third solid electrolyte foil; and
a heating element arranged between the second and third solid electrolyte foils,
wherein the third solid electrolyte foil has a thickness dimensioned so that the heating element is approximately equidistant from two large surfaces of the sensor element.

43. (New) A method for manufacturing a sensor element for determining a concentration of gas components in gas mixtures, comprising:
providing a solid electrolyte foil; and
applying a solid electrolyte layer to the solid electrolyte foil by screen-printing a pasty ceramic material, the solid electrolyte layer including a measuring gas chamber and a reference gas channel.

44. (New) The method as recited in claim 43, wherein the solid electrolyte layer delineates a boundary for the measuring gas chamber and the reference gas channel.

45. (New) The method as recited in claim 43, further comprising the step of:
producing at least one supporting element in the reference gas channel using the solid electrolyte layer.

46. (New) The method as recited in claim 43, wherein the pasty ceramic material and the solid electrolyte foil include the same solid electrolyte.

47. (New) The method as recited in claim 43, further comprising the steps of:
performing a thermal treatment after printing to convert the pasty ceramic material is converted into a ceramic form.

Remarks

This Preliminary Amendment cancels without prejudice claims 1-23, in the underlying PCT Application No. PCT/DE00/02879, and adds new claims 24 to 47. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification includes the Abstract and contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/02879 includes an International Search Report, dated January 25, 2001. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. An English translation of the Search Report accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

Dated: 30 April 2011

By: *[Signature]* (Reg. No. 36,094)

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SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION
IN GAS MIXTURES AND METHOD FOR ITS MANUFACTURE

Field Of The Invention

The present invention relates to a sensor element for determining the oxygen concentration in gas mixtures and also relates to a method for manufacturing such sensors.

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Background Information

An oxygen sensor, also referred to as a broadband lambda probe, is normally used today for controlling the air-fuel ratio of combustion mixtures for motor vehicle engines. This sensor relies on the interaction of an electrochemical pump cell and a concentration cell. With the aid of the electrodes of the pump cell, oxygen is pumped from a measuring gas chamber of the sensor into the exhaust gas stream, or from the exhaust gas stream into the measuring gas chamber. To this end, one of the pump electrodes is deposited in the measuring gas chamber, and one is deposited on the outer surface of the sensor element and exposed to the exhaust gas stream. The electrodes of the concentration cell are arranged so that one is situated in the measuring gas chamber, but the other is situated with the in a reference gas channel normally filled with air. This arrangement allows the oxygen potential of the measuring electrode in the measuring gas chamber to be compared with the reference oxygen potential of the reference electrode, in the form of a measurable voltage applied at the concentration cell. With regard to measuring technique, the pump voltage to be applied at the electrodes of the pump cell is selected so as to maintain a predetermined voltage value at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a test signal proportional to the oxygen concentration.

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The measuring gas chamber and the reference gas channel are usually positioned in different planes of the sensor element,

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so that the reference gas channel is located underneath the measuring gas chamber. However, this requires at least one additional, solid electrolyte layer, which contains the reference gas channel. German Patent Application No. 196 47 144 describes, at least as a variant, an element for measuring the air-fuel ratio, where the reference gas channel is situated in the same layer plane as the measuring gas chamber. However, in the case of such a layer, experience shows that a minimum layer thickness is dependent on stamping processes during manufacture. In addition, the modified arrangement of the gas chambers creates problems relating to measuring technique, since such an arrangement increases the internal resistance of the concentration cell, and results in a one-sided loading of the measuring and reference electrodes.

Summary Of The Invention

The sensor element and method according to the present invention, respectively, have the advantage that the layer thickness of the layer containing both the measuring gas chamber and the reference gas channel can be varied. A layer that has a very low layer thickness, or a layer having very filagree-like boundaries of the gas chambers contained therein, and having supporting elements not connected to the boundaries may be attained.

The effect of adapting the partition situated between the measuring gas chamber and the reference gas channel on the geometry of the measuring electrode situated in the measuring gas chamber, is such that only a small clearance exists between the measuring gas chamber and the reference gas channel. Therefore, and therefore, the internal resistance of the sensor-element concentration cell is decreased.

Furthermore, it is advantageous to design the reference electrode located in the reference gas channel in such a manner that it adapts to the geometry of the partition between the measuring gas chamber and the reference gas channel. Also

the surface of the reference electrode facing in the direction of the partition is as large as possible. This permits a uniform loading of the entire electrode surface, and decreases the electrical resistance of the concentration cell that is made of the measuring electrode and the reference electrode. This is achieved in an advantageous manner when the measuring electrode is circular and the reference electrode is led around the measuring gas chamber, which is circular as well. In addition, the internal resistance of this sensor element's concentration cell exhibits an easily-evaluated temperature dependence, which can be used to control the temperature of the sensor element.

In another exemplary embodiment, the measuring and pump electrodes, which are usually arranged separately in the measuring gas chamber, are advantageously combined into one electrode. This allows one layer plane to be dispensed with, and further simplifies the sensor design.

By appropriately designing the layer assembly, the resistance heater intended for the sensor element into the sensor element can be incorporated so that the resistance heater is equidistant from the two large surfaces of the sensor element. This results in low mechanical stresses especially on the heater-side edges of the sensor element during the heating phase and during operation.

Brief Description of the Drawings

Figure 1 shows a cross-section through the large surface of the sensor element according to the present invention.

Figure 2 shows a longitudinal section through the sensor element, along line II-II in Figure 1.

Figure 3 shows a longitudinal section through the sensor element according to a third exemplary embodiment.

Figure 4 shows a longitudinal section through the sensor element according to a fourth exemplary embodiment.

Figure 5 shows a cross-section through the large surface of the sensor element according to an exemplary embodiment.

Figure 6 shows a cross-section through the large surface of the sensor element according to an additional exemplary embodiment.

Detailed Description

Figures 1 and 2 show a basic design of a first example embodiment according to the present invention. As shown, a planar sensor element 10 of an electrochemical gas sensor has a plurality of solid electrolyte layers, for example, 11a, 11b, 11c, and 11d, that conduct oxygen ions. In this context, solid electrolyte layers 11a, 11c, and 11d are designed as ceramic foils, and form a planar ceramic body. They are made of a solid electrolyte material that conducts oxygen ions, such as ZrO_2 stabilized or partially stabilized by Y_2O_3 .

In contrast, solid electrolyte layer 11b is produced by screen-printing a pasty ceramic material, e.g., on solid electrolyte layer 11a. The solid electrolyte material used as a ceramic component of the pasty material may be the same as the one which makes up solid electrolyte layers 11a, 11c, and 11d.

The integrated form of the planar ceramic body of sensor element 10 is produced in a conventional manner, by laminating together the ceramic foils printed over with solid electrolyte layer 11b and functional layers, and by subsequently sintering the laminated structure.

Sensor element 10 contains two gas chambers, a measuring gas chamber 13 and a reference gas channel 15. These are situated

in the same layer plane, e.g., 11b, and separated from each other in a gas-tight manner, by a partition 12. Reference gas channel 15 is put in contact with a reference gas atmosphere, by a gas intake 17 whose one end leads out of the planar body of sensor element 10. It has an end 16 on the side of the measuring gas chamber, and an end 18 on the side of the gas intake. Supporting elements 28 are integrated in the middle of reference gas channel 15, along a longitudinal axis of the sensor element. These permit the reference gas channel to have a wide design, without decreasing the rigidity of the sensor element. As an alternative, the reference gas channel can also be at least partially filled in with a porous ceramic material.

For example, measuring gas chamber 13 is designed to be circular, and is connected to the gas-mixture atmosphere by opening 25. Opening 25 is situated in solid electrolyte layer 11a, normal to the surface of sensor element 10.

An outer pump electrode 23, which can be covered by a porous protective layer 26, and can be arranged so as to encircle opening 25, is positioned on the large surface of sensor element 10 directly facing the measuring gas, on solid electrolyte layer 11a. Situated on the side of solid electrolyte layer 11a that faces the measuring gas chamber is corresponding inner pump electrode 20, which is designed to be circular as well, so as to be adapted to the circular geometry of measuring gas chamber 13. Together, the two pump electrodes form a pump cell.

In measuring gas chamber 13, a measuring electrode 21 is located opposite to inner pump electrode 20. This measuring electrode may also have a circular design. Corresponding reference electrode 22 is situated in reference gas channel 15. In this context, the reference electrode can be formed on the side of reference gas channel 15 that points in the direction of the large surface of the sensor element exposed

to the gas-mixture atmosphere, or the reference electrode can also be formed on the side of reference gas channel 15 that is opposite to the large surface of the sensor element exposed to the gas-mixture atmosphere. Measuring and reference electrodes 21, 22 form a Nernst or concentration cell together.

A porous diffusion barrier 27 is arranged inside measuring gas chamber 13, in front of inner pump electrode 20 and measuring electrode 21, in the diffusion direction of the measuring gas. Porous diffusion barrier 27 constitutes a diffusion resistor with regard to the gas diffusing towards electrodes 20, 21. In the case of a reference gas channel 15 filled with a porous ceramic material, diffusion barrier 27 and the filling of reference gas channel 15 may be made of the same material, in order to efficiently manufacture them in one method step.

Outer pump electrode 23 is contacted by a printed circuit trace 30, which is deposited on the surface of solid electrolyte layer 11a. Measuring electrode 21 and reference electrode 22 are contacted by printed circuit traces 31, 32, which are led between solid electrolyte layers 11b and 11c, and are connected to the large surface of the sensor element by plated-through holes not shown. All of the printed circuit traces are insulated from the solid electrolyte layers by insulation 35, which, for example, can be made of Al_2O_3 .

In order to ensure that the measuring gas components are brought into thermodynamic equilibrium at the electrodes, all of the electrodes used are made of a catalytically active material, such as platinum, the electrode material for all of the electrodes being applied as cermet in a conventional manner, in order to sinter the electrode material to the ceramic foils.

In addition, a resistance heater 40 is situated between solid electrolyte layers 11c and 11d, and is embedded in electrical insulation 41, e.g., made of Al_2O_3 . Sensor element 10 is heated

to the appropriate operating temperature of, e.g., 750°C, by resistance heater 40.

Together, inner and outer pump electrodes 20, 23 form a pump cell. This transports oxygen out of and into measuring gas chamber 13. Measuring electrode 21 and reference electrode 22 are interconnected as a concentration cell. This allows the oxygen potential of measuring electrode 21, which is a function of the oxygen concentration in measuring gas chamber 13, to be directly compared to the constant oxygen potential of reference electrode 22, in the form of a measurable electrical voltage. The level of the pump voltage to be applied to the pump cell is selected in such a manner, that a constant voltage, e.g., 450 mV, exists at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a measuring signal proportional to the oxygen concentration in the exhaust gas.

As discussed above, the problem with this overall arrangement is that the parallel arrangement of the gas chambers markedly increases the internal resistance of the concentration cell. This is caused by the longer path that the charge carriers must cover inside the solid electrolyte. For this reason, measuring and reference electrodes 21, 22 are spatially arranged to be as close as possible to each other. This is primarily rendered possible by the screen-printing technique used in manufacturing the sensor element, since, in this manner, partition 12 can be designed to be very thin. The relatively short distance of the two electrodes from each other results in an internal resistance of the concentration cell which is only slightly greater than conventional sensors, and can be used to regulate the temperature of the sensor element.

The sharply one-sided loading of the measuring and reference electrodes, in comparison with conventional types of sensors having the gas chambers arranged one over another, represents

an additional problem. Since the charge carriers inside the solid electrolyte prefer the shortest path between the two electrodes, the compartments of measuring and reference electrodes 21, 22 facing the other respective electrode are the most highly loaded. This fact is particularly taken into account by adapting the geometry of reference gas channel 15 and reference electrode 22. Along these lines, reference electrode 22 is designed in such a manner that its top surface reaches its maximum dimension at the end of reference channel 15 on the side of the measuring gas, so that the center of mass of the electrode surface is shifted as closely as possible to the center point of measuring electrode 21.

A second exemplary embodiment is represented in Figure 3. In this exemplary embodiment, both reference gas channel 15 and reference electrode 22 are led around measuring gas chamber 13. In this manner, the two form a segment of a circular ring. This enlarges the compartment of reference electrode 22 on the measuring-gas side, and reduces the load on the electrode. In the d.c. operation used to control the pump voltage, the reference electrode is in direct contact with the reference gas atmosphere. However, the sensor-element temperature control, which is based on determining the internal resistance of the Nernst cell, can also be implemented using a.c. voltage. In this case, the contact with the reference gas atmosphere is not required. Therefore, it is sufficient when only a part of the reference-electrode surface is directly exposed to the reference gas atmosphere. This allows the sensor design represented in Figure 3 to be simplified, as shown in Figure 4. Reference electrode 22 continues to be led around measuring gas chamber 13 in a circular ring segment, but reference gas channel 15 does not.

In addition, the spatial dimensions of measuring electrode 21 are not restricted by the size of measuring gas chamber 13. Figure 5 depicts a sensor design that includes a measuring electrode 21, whose dimensions extend beyond measuring gas

chamber 13, and thus reduce the internal resistance of the Nernst cell. Two reference electrodes 22, 24 are also provided.

5 An additional exemplary embodiment is represented in Figure 6. It is possible to combine inner pump electrode 20 and measuring electrode 21 into measuring electrode 21a. If this measuring electrode 21a is situated on the side of solid electrolyte layer 11a that faces the gas chambers, as is also
10 the case with reference electrode 22, then one can dispense with inserting solid electrolyte layer 11c, and the sensor design is simplified further. By selecting an appropriately thick, solid electrolyte layer 11d, it is then possible to integrate heating element 40 into the sensor element in such a manner that it is equidistant from the two large surfaces of the sensor element, and is therefore arranged symmetrically. This sharply reduces the mechanical stresses occurring during the heating phase, above all, at the edges of the sensor element.

15 The sensor element according to the present invention and the method for manufacturing it are not limited to the specified, practical options for refinement, but rather further specific embodiments are possible which contain one or more solid
20 electrolyte layers produced using a printing method.
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Abstract Of The Disclosure

A sensor element for determining the concentration of gas components in gas mixtures, particularly for determining the oxygen concentration in exhaust gases of internal combustion engines. It contains a pump cell, which pumps oxygen into or out of a measuring gas chamber, as well as a concentration cell, which has a reference electrode situated in the reference gas channel, and has a measuring electrode. The measuring gas chamber and the reference gas channel are situated in the same layer plane of the sensor element, and are separated from each other by a partition, which is produced by applying a ceramic paste to an adjacent, solid electrolyte foil.

SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION
IN GAS MIXTURES AND METHOD FOR ITS MANUFACTURE

Field Of The Invention

The present invention relates to a sensor element for determining the oxygen concentration in gas mixtures and also relates to a method for manufacturing [it, according to the definition of the species in the independent claims.] such sensors.

Background Information

An oxygen sensor, [which is] also referred to as a broadband lambda probe, [and] is normally used today for controlling the air-fuel ratio of combustion mixtures for motor vehicle engines[, is based]. This sensor relies on the interaction of an electrochemical pump cell and a concentration cell. With the aid of the electrodes of the pump cell, oxygen is pumped from a measuring gas chamber of the sensor into the exhaust gas stream, or from the exhaust gas stream into the measuring gas chamber. To this end, one of the pump electrodes is deposited in the measuring gas chamber, and one is deposited on the [sensor-element] outer surface of the sensor element and exposed to the exhaust gas stream. The electrodes of the concentration cell are arranged so that one is [also] situated in the measuring gas chamber, but the other is situated with the in a reference gas channel normally filled with air. This [set-up] arrangement allows the oxygen potential of the measuring electrode in the measuring gas chamber to be compared with the reference oxygen potential of the reference electrode, in the form of a measurable voltage applied at the concentration cell. With regard to measuring technique, the pump voltage to be applied at the electrodes of the pump cell is selected so as to maintain a predetermined voltage value at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a test signal

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proportional to the oxygen concentration.

The measuring gas chamber and the reference gas channel are usually positioned in different planes of the sensor element, so that the reference gas channel is located underneath the measuring gas chamber. However, this requires at least one additional, solid electrolyte layer, which contains the reference gas channel. [DE OS] German Patent Application No. 196 47 144 [A1] describes, at least as a variant, an element for measuring the air-fuel ratio, where the reference gas channel is situated in the same layer plane as the measuring gas chamber. However, in the case of such a layer, experience shows that a minimum layer thickness is dependent on stamping processes during manufacture [the]. In addition, the modified [set-up] arrangement of the gas chambers creates problems relating to measuring technique, since such [a set-up i and ncreases] an arrangement increases the internal resistance of the concentration cell, and results in a one-sided loading of the measuring and reference electrodes.

Summary [of the] Of The Invention

The sensor element and method according to the present invention, [having the characterizing features of Claims 1 and 19,] respectively, have the advantage that the layer thickness of the layer containing both the measuring gas chamber and the reference gas channel can be varied. [Above all, one can attain a] A layer that has a very low layer thickness, or a layer having very filagree-like boundaries of the gas chambers contained therein, and having supporting elements not connected to the boundaries may be attained.

[.

Advantageous further refinements and improvements of the sensor element mentioned in the independent claims are

rendered possible by the measures specified in the dependent claims.] The effect of adapting the partition situated between the measuring gas chamber and the reference gas channel[, to] on the geometry of the measuring electrode situated in the measuring gas chamber, is such[,] that only a small clearance exists between the measuring gas chamber and the reference gas channel. Therefore, and therefore, the internal resistance of the sensor-element concentration cell is decreased.

Furthermore, it is [especially] advantageous to design the reference electrode located in the reference gas channel[,] in such a manner[,] that[, first of all,] it adapts to the geometry of the partition between the measuring gas chamber and the reference gas channel[, and secondly, its surface]. Also the surface of the reference electrode facing in the direction of the partition is as large as possible. This permits a uniform loading of the entire electrode surface, and decreases the electrical resistance of the concentration cell that is made of the measuring electrode and the reference electrode. This is achieved in an [especially] advantageous manner[,] when the measuring electrode is circular and the reference electrode is led around the measuring gas chamber, which is circular as well. In addition, the internal resistance of this sensor element's concentration cell exhibits an easily [evaluable]-evaluated temperature dependence, which can be used to control the temperature of the sensor element.

In another exemplary embodiment, the measuring and pump electrodes, which are usually arranged separately in the measuring gas chamber, are advantageously combined into one electrode. This allows one layer plane to be dispensed with, and further simplifies the sensor design.

By appropriately designing the layer assembly, [one can incorporate] the resistance heater intended for the sensor element[,] into the sensor element[, in such a particularly advantageous manner,] can be incorporated so that the

resistance heater is equidistant from the two large surfaces of the sensor element. This results in low mechanical stresses[, above all,] especially on the heater-side edges of the sensor element[,] during the heating phase and during operation.

Brief Description of the Drawings [Drawing

An exemplary embodiment of the present invention is represented in the drawing, and explained in detail in the following description.]

Figure 1 shows a cross-section through the large surface of the sensor element according to the present invention[.].

Figure 2 shows a longitudinal section through the sensor element, along line II-II in Figure 1[, Figures 3 and 4 show].

Figure 3 shows a longitudinal [sections] section through the sensor element according to a third [and fourth] exemplary embodiment[, and Figures 5 and 6 show a cross-].

Figure 4 shows a longitudinal section through [the large surface of] the sensor element according to [two additional exemplary embodiments.] a fourth exemplary embodiment.

[Exemplary Embodiments] Figure 5 shows a cross-section through the large surface of the sensor element according to an exemplary embodiment.

Figure 6 shows a cross-section through the large surface of the sensor element according to an additional exemplary embodiment.

Detailed Description

Figures 1 and 2 show a basic design of a first [specific]

example embodiment according to the present invention.

[Designated by reference numeral 10 is] As shown, a planar sensor element 10 of an electrochemical gas sensor[, which, for example,] has a plurality of solid electrolyte layers, for example, 11a, 11b, 11c, and 11d, that conduct oxygen ions. In this context, solid electrolyte layers 11a, 11c, and 11d are designed as ceramic foils, and form a planar ceramic body. They are made of a solid electrolyte material that conducts oxygen ions, such as ZrO_2 stabilized or partially stabilized by Y_2O_3 .

In contrast, solid electrolyte layer 11b is produced by screen-printing a pasty ceramic material, e.g., on solid electrolyte layer 11a. The solid electrolyte material used as a ceramic component of the pasty material [is preferably] may be the same as the one which makes up solid electrolyte layers 11a, 11c, and 11d.

The integrated form of the planar ceramic body of sensor element 10 is produced in a [known] conventional manner, by laminating together the ceramic foils printed over with solid electrolyte layer 11b and functional layers, and by subsequently sintering the laminated structure.

Sensor element 10 contains two gas chambers, a measuring gas chamber 13 and a reference gas channel 15. These are situated in the same layer plane, e.g., 11b, and separated from each other in a gas-tight manner, by a partition 12. Reference gas channel 15 is put in contact with a reference gas atmosphere, by a gas intake 17 whose one end leads out of the planar body of sensor element 10. It has an end 16 on the side of the measuring gas chamber, and an end 18 on the side of the gas intake. Supporting elements 28 are integrated in the middle of reference gas channel 15, along a longitudinal axis of the sensor element. These permit the reference gas channel to have a wide design, without decreasing the rigidity of the sensor

element. As an alternative, the reference gas channel can also be at least partially filled in with a porous ceramic material.

5 For example, measuring gas chamber 13 is designed to be circular, and is connected to the gas-mixture atmosphere by opening 25. Opening 25 is situated in solid electrolyte layer 11a, normal to the surface of sensor element 10.

10 An outer pump electrode 23, which can be covered by a porous protective layer 26, and can be arranged so as to encircle opening 25, is positioned on the large surface of sensor element 10 directly facing the measuring gas, on solid electrolyte layer 11a. Situated on the side of solid electrolyte layer 11a that faces the measuring gas chamber is corresponding inner pump electrode 20, which is designed to be circular as well, so as to be adapted to the circular geometry of measuring gas chamber 13. Together, the two pump electrodes form a pump cell.

20 In measuring gas chamber 13, a measuring electrode 21 is located opposite to inner pump electrode 20. This measuring electrode may also have a circular design. Corresponding reference electrode 22 is situated in reference gas channel 15. In this context, the reference electrode can be formed on the side of reference gas channel 15 that points in the direction of the large surface of the sensor element exposed to the gas-mixture atmosphere, or the reference electrode can also be formed on the side of reference gas channel 15 that is opposite to the large surface of the sensor element exposed to the gas-mixture atmosphere. Measuring and reference electrodes 21, 22 form a Nernst or concentration cell together.

35 A porous diffusion barrier 27 is arranged inside measuring gas chamber 13, in front of inner pump electrode 20 and measuring electrode 21, in the diffusion direction of the measuring gas.

Porous diffusion barrier 27 constitutes a diffusion resistor with regard to the gas diffusing towards electrodes 20, 21. In the case of a reference gas channel 15 filled with a porous ceramic material, diffusion barrier 27 and the filling of reference gas channel 15 may be made of the same material, in order to efficiently manufacture them in one method step.

Outer pump electrode 23 is contacted by a printed circuit trace 30, which is deposited on the surface of solid electrolyte layer 11a. Measuring electrode 21 and reference electrode 22 are contacted by printed circuit traces 31, 32, which are led between solid electrolyte layers 11b and 11c, and are connected to the large surface of the sensor element by plated-through holes not shown. All of the printed circuit traces are insulated from the solid electrolyte layers by insulation 35, which, for example, can be made of Al_2O_3 .

In order to ensure that the measuring gas components are brought into thermodynamic equilibrium at the electrodes, all of the electrodes used are made of a catalytically active material, such as platinum, the electrode material for all of the electrodes being applied as cermet in a conventional manner [known per se], in order to sinter the electrode material to the ceramic foils.

In addition, a resistance heater 40 is situated between solid electrolyte layers 11c and 11d, and is embedded in electrical insulation 41, e.g., made of Al_2O_3 . Sensor element 10 is heated to the appropriate operating temperature of, e.g., 750°C, by resistance heater 40.

Together, inner and outer pump electrodes 20, 23 form a pump cell. This transports oxygen out of and into measuring gas chamber 13. Measuring electrode 21 and reference electrode 22 are interconnected as a concentration cell. This allows the oxygen potential of measuring electrode 21, which is a

function of the oxygen concentration in measuring gas chamber 13, to be directly compared to the constant oxygen potential of reference electrode 22, in the form of a measurable electrical voltage. The level of the pump voltage to be applied to the pump cell is selected in such a manner, that a constant voltage, e.g., 450 mV, exists at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a measuring signal proportional to the oxygen concentration in the exhaust gas.

As [already mentioned at the outset] discussed above, the problem with this overall [set-up] arrangement is that the parallel arrangement of the gas chambers markedly increases the internal resistance of the concentration cell. This is caused by the longer path that the charge carriers must cover inside the solid electrolyte. For this reason, measuring and reference electrodes 21, 22 are spatially arranged to be as close as possible to each other. This is primarily rendered possible by the screen-printing technique used in manufacturing the sensor element, since, in this manner, partition 12 can be designed to be very thin. The relatively short distance of the two electrodes from each other results in an internal resistance of the concentration cell[,] which is only slightly [increased in comparison with] greater than conventional sensors, and can be used to regulate the temperature of the sensor element.

The sharply one-sided loading of the measuring and reference electrodes, in comparison with conventional types of sensors having the gas chambers arranged one over another, represents an additional problem. Since the charge carriers inside the solid electrolyte prefer the shortest path between the two electrodes, the compartments of measuring and reference electrodes 21, 22 facing the other respective electrode are the most highly loaded. This fact is particularly taken into account by adapting the geometry of reference gas channel 15

and reference electrode 22. Along these lines, reference electrode 22 is designed in such a manner[,] that its top surface reaches its maximum dimension at the end of reference channel 15 on the side of the measuring gas, so that the center of mass of the electrode surface is shifted as closely as possible to the center point of measuring electrode 21.

A second exemplary embodiment is represented in Figure 3. In this exemplary embodiment, both reference gas channel 15 and reference electrode 22 are led around measuring gas chamber 13. In this manner, the two form a segment of a circular ring. This enlarges the compartment of reference electrode 22 on the measuring-gas side, and reduces the load on the electrode. In the d.c. operation used to control the pump voltage, the reference electrode [does need to be] is in direct contact with the reference gas atmosphere. However, the sensor-element temperature control, which is based on determining the internal resistance of the Nernst cell, can also be implemented using a.c. voltage. In this case, the contact with the reference gas atmosphere is not [necessary] required. Therefore, it is sufficient when only a part of the reference-electrode surface is directly exposed to the reference gas atmosphere. This allows the sensor design represented in Figure 3 to be simplified, as shown in Figure 4. Reference electrode 22 [does continue] continues to be led around measuring gas chamber 13 in a circular ring segment, but reference gas channel 15 does not.

In addition, the spatial dimensions of measuring electrode 21 are not restricted by the size of measuring gas chamber 13. Figure 5 depicts a sensor design that includes a measuring electrode 21, whose dimensions extend beyond measuring gas chamber 13, and thus reduce the internal resistance of the Nernst cell. Two reference electrodes 22, 24 are also provided.

An additional exemplary embodiment is represented in Figure 6. It is possible to combine inner pump electrode 20 and measuring electrode 21 into measuring electrode 21a. If this measuring electrode 21a is situated on the side of solid electrolyte layer 11a that faces the gas chambers, as is also the case with reference electrode 22, then one can dispense with inserting solid electrolyte layer 11c, and the sensor design is simplified further. By selecting an appropriately thick, solid electrolyte layer 11d, it is then possible to integrate heating element 40 into the sensor element in such a manner[,] that it is equidistant from the two large surfaces of the sensor element, and is therefore arranged symmetrically. This sharply reduces the mechanical stresses occurring during the heating phase, above all, at the edges of the sensor element.

The sensor element according to the present invention and the method for manufacturing it are not limited to the specified, practical options for refinement, but rather further specific embodiments are [conceivable,] possible which contain one or more solid electrolyte layers produced[,] using a printing method.

Abstract Of The Disclosure

5 A sensor element for determining the concentration of gas
components in gas mixtures, [especially] particularly for
determining the oxygen concentration in exhaust gases of
internal combustion engines. It contains a pump cell, which
pumps oxygen into or out of a measuring gas chamber, as well
as a concentration cell, which has a reference electrode
10 situated in the reference gas channel, and has a measuring
electrode. The measuring gas chamber and the reference gas
channel are situated in the same layer plane of the sensor
element, and are separated from each other by a partition,
which is produced by applying a ceramic paste to an adjacent,
solid electrolyte foil.

[Figure 1]

2/PRTS

SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION
IN GAS MIXTURES AND METHOD FOR ITS MANUFACTURE

The present invention relates to a sensor element for determining the oxygen concentration in gas mixtures and a method for manufacturing it, according to the definition of the species in the independent claims.

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Background Information

An oxygen sensor, which is also referred to as a broadband lambda probe, and is normally used today for controlling the air-fuel ratio of combustion mixtures for motor vehicle engines, is based on the interaction of an electrochemical pump cell and a concentration cell. With the aid of the electrodes of the pump cell, oxygen is pumped from a measuring gas chamber of the sensor into the exhaust gas stream, or from the exhaust gas stream into the measuring gas chamber. To this end, one of the pump electrodes is deposited in the measuring gas chamber, and one is deposited on the sensor-element outer surface exposed to the exhaust gas stream. The electrodes of the concentration cell are arranged so that one is also situated in the measuring gas chamber, but the other is situated in a reference gas channel normally filled with air. This set-up allows the oxygen potential of the measuring electrode in the measuring gas chamber to be compared with the reference oxygen potential of the reference electrode, in the form of a measurable voltage applied at the concentration cell. With regard to measuring technique, the pump voltage to be applied at the electrodes of the pump cell is selected so as to maintain a predetermined voltage value at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a test signal proportional to the oxygen concentration.

The measuring gas chamber and the reference gas channel are

usually positioned in different planes of the sensor element,
so that the reference gas channel is located underneath the
measuring gas chamber. However, this requires at least one
additional, solid electrolyte layer, which contains the
reference gas channel. DE OS 196 47 144 A1 describes, at least
as a variant, an element for measuring the air-fuel ratio,
where the reference gas channel is situated in the same layer
plane as the measuring gas chamber. However, in the case of
such a layer, experience shows that a minimum layer thickness
is dependent on stamping processes during manufacture the. In
addition, the modified set-up of the gas chambers creates
problems relating to measuring technique, since such a set-up
increases the internal resistance of the concentration
cell, and results in a one-sided loading of the measuring and
reference electrodes.

Summary of the Invention

The sensor element and method according to the present
invention, having the characterizing features of Claims 1 and
19, respectively, have the advantage that the layer thickness
of the layer containing both the measuring gas chamber and the
reference gas channel can be varied. Above all, one can attain
a layer that has a very low layer thickness, or a layer having
very filagree-like boundaries of the gas chambers contained
therein, and having supporting elements not connected to the
boundaries.

Advantageous further refinements and improvements of the
sensor element mentioned in the independent claims are
rendered possible by the measures specified in the dependent
claims. The effect of adapting the partition situated between
the measuring gas chamber and the reference gas channel, to
the geometry of the measuring electrode situated in the
measuring gas chamber, is such, that only a small clearance
exists between the measuring gas chamber and the reference gas
channel, and therefore, the internal resistance of the

sensor-element concentration cell is decreased. Furthermore, it is especially advantageous to design the reference electrode located in the reference gas channel, in such a manner, that, first of all, it adapts to the geometry of the partition between the measuring gas chamber and the reference gas channel, and secondly, its surface facing in the direction of the partition is as large as possible. This permits a uniform loading of the entire electrode surface, and decreases the electrical resistance of the concentration cell that is made of the measuring electrode and the reference electrode. This is achieved in an especially advantageous manner, when the measuring electrode is circular and the reference electrode is led around the measuring gas chamber, which is circular as well. In addition, the internal resistance of this sensor element's concentration cell exhibits an easily evaluable temperature dependence, which can be used to control the temperature of the sensor element.

In another exemplary embodiment, the measuring and pump electrodes, which are usually arranged separately in the measuring gas chamber, are advantageously combined into one electrode. This allows one layer plane to be dispensed with, and further simplifies the sensor design.

By appropriately designing the layer assembly, one can incorporate the resistance heater intended for the sensor element, into the sensor element, in such a particularly advantageous manner, that the resistance heater is equidistant from the two large surfaces of the sensor element. This results in low mechanical stresses, above all, on the heater-side edges of the sensor element, during the heating phase and during operation.

Brief Description of the Drawing

An exemplary embodiment of the present invention is represented in the drawing, and explained in detail in the

following description. Figure 1 shows a cross-section through the large surface of the sensor element according to the present invention, Figure 2 shows a longitudinal section through the sensor element, along line II-II in Figure 1, Figures 3 and 4 show longitudinal sections through the sensor element according to a third and fourth exemplary embodiment, and Figures 5 and 6 show a cross-section through the large surface of the sensor element according to two additional exemplary embodiments.

Exemplary Embodiments

Figures 1 and 2 show a basic design of a first specific embodiment according to the present invention. Designated by reference numeral 10 is a planar sensor element of an electrochemical gas sensor, which, for example, has a plurality of solid electrolyte layers 11a, 11b, 11c, and 11d that conduct oxygen ions. In this context, solid electrolyte layers 11a, 11c, and 11d are designed as ceramic foils, and form a planar ceramic body. They are made of a solid electrolyte material that conducts oxygen ions, such as ZrO_2 stabilized or partially stabilized by Y_2O_3 .

In contrast, solid electrolyte layer 11b is produced by screen-printing a pasty ceramic material, e.g. on solid electrolyte layer 11a. The solid electrolyte material used as a ceramic component of the pasty material is preferably the same as the one which makes up solid electrolyte layers 11a, 11c, and 11d.

The integrated form of the planar ceramic body of sensor element 10 is produced in a known manner, by laminating together the ceramic foils printed over with solid electrolyte layer 11b and functional layers, and by subsequently sintering the laminated structure.

Sensor element 10 contains two gas chambers, a measuring gas

chamber 13 and a reference gas channel 15. These are situated in the same layer plane, e.g. 11b, and separated from each other in a gas-tight manner, by a partition 12. Reference gas channel 15 is put in contact with a reference gas atmosphere, by a gas intake 17 whose one end leads out of the planar body of sensor element 10. It has an end 16 on the side of the measuring gas chamber, and an end 18 on the side of the gas intake. Supporting elements 28 are integrated in the middle of reference gas channel 15, along a longitudinal axis of the sensor element. These permit the reference gas channel to have a wide design, without decreasing the rigidity of the sensor element. As an alternative, the reference gas channel can also be at least partially filled in with a porous ceramic material.

For example, measuring gas chamber 13 is designed to be circular, and is connected to the gas-mixture atmosphere by opening 25. Opening 25 is situated in solid electrolyte layer 11a, normal to the surface of sensor element 10.

An outer pump electrode 23, which can be covered by a porous protective layer 26, and can be arranged so as to encircle opening 25, is positioned on the large surface of sensor element 10 directly facing the measuring gas, on solid electrolyte layer 11a. Situated on the side of solid electrolyte layer 11a that faces the measuring gas chamber is corresponding inner pump electrode 20, which is designed to be circular as well, so as to be adapted to the circular geometry of measuring gas chamber 13. Together, the two pump electrodes form a pump cell.

In measuring gas chamber 13, a measuring electrode 21 is located opposite to inner pump electrode 20. This measuring electrode may also have a circular design. Corresponding reference electrode 22 is situated in reference gas channel 15. In this context, the reference electrode can be formed on the side of reference gas channel 15 that points in the

direction of the large surface of the sensor element exposed to the gas-mixture atmosphere, or the reference electrode can also be formed on the side of reference gas channel 15 that is opposite to the large surface of the sensor element exposed to the gas-mixture atmosphere. Measuring and reference electrodes 21, 22 form a Nernst or concentration cell together.

A porous diffusion barrier 27 is arranged inside measuring gas chamber 13, in front of inner pump electrode 20 and measuring electrode 21, in the diffusion direction of the measuring gas. Porous diffusion barrier 27 constitutes a diffusion resistor with regard to the gas diffusing towards electrodes 20, 21. In the case of a reference gas channel 15 filled with a porous ceramic material, diffusion barrier 27 and the filling of reference gas channel 15 may be made of the same material, in order to efficiently manufacture them in one method step.

Outer pump electrode 23 is contacted by a printed circuit trace 30, which is deposited on the surface of solid electrolyte layer 11a. Measuring electrode 21 and reference electrode 22 are contacted by printed circuit traces 31, 32, which are led between solid electrolyte layers 11b and 11c, and are connected to the large surface of the sensor element by plated-through holes not shown. All of the printed circuit traces are insulated from the solid electrolyte layers by insulation 35, which, for example, can be made of Al_2O_3 .

In order to ensure that the measuring gas components are brought into thermodynamic equilibrium at the electrodes, all of the electrodes used are made of a catalytically active material, such as platinum, the electrode material for all of the electrodes being applied as cermet in a manner known per se, in order to sinter the electrode material to the ceramic foils.

In addition, a resistance heater 40 is situated between solid electrolyte layers 11c and 11d, and is embedded in electrical

insulation 41, e.g. made of Al_2O_3 . Sensor element 10 is heated to the appropriate operating temperature of, e.g. 750°C , by resistance heater 40.

Together, inner and outer pump electrodes 20, 23 form a pump cell. This transports oxygen out of and into measuring gas chamber 13. Measuring electrode 21 and reference electrode 22 are interconnected as a concentration cell. This allows the oxygen potential of measuring electrode 21, which is a function of the oxygen concentration in measuring gas chamber 13, to be directly compared to the constant oxygen potential of reference electrode 22, in the form of a measurable electrical voltage. The level of the pump voltage to be applied to the pump cell is selected in such a manner, that a constant voltage, e.g. 450 mV, exists at the concentration cell. The pump current flowing between the electrodes of the pump cell is utilized as a measuring signal proportional to the oxygen concentration in the exhaust gas.

As already mentioned at the outset, the problem with this overall set-up is that the parallel arrangement of the gas chambers markedly increases the internal resistance of the concentration cell. This is caused by the longer path that the charge carriers must cover inside the solid electrolyte. For this reason, measuring and reference electrodes 21, 22 are spatially arranged to be as close as possible to each other. This is primarily rendered possible by the screen-printing technique used in manufacturing the sensor element, since, in this manner, partition 12 can be designed to be very thin. The relatively short distance of the two electrodes from each other results in an internal resistance of the concentration cell, which is only slightly increased in comparison with conventional sensors, and can be used to regulate the temperature of the sensor element.

The sharply one-sided loading of the measuring and reference electrodes, in comparison with conventional types of sensors

having the gas chambers arranged one over another, represents an additional problem. Since the charge carriers inside the solid electrolyte prefer the shortest path between the two electrodes, the compartments of measuring and reference electrodes 21, 22 facing the other respective electrode are the most highly loaded. This fact is particularly taken into account by adapting the geometry of reference gas channel 15 and reference electrode 22. Along these lines, reference electrode 22 is designed in such a manner, that its top surface reaches its maximum dimension at the end of reference channel 15 on the side of the measuring gas, so that the center of mass of the electrode surface is shifted as closely as possible to the center point of measuring electrode 21.

A second exemplary embodiment is represented in Figure 3. In this exemplary embodiment, both reference gas channel 15 and reference electrode 22 are led around measuring gas chamber 13. In this manner, the two form a segment of a circular ring. This enlarges the compartment of reference electrode 22 on the measuring-gas side, and reduces the load on the electrode. In the d.c. operation used to control the pump voltage, the reference electrode does need to be in direct contact with the reference gas atmosphere. However, the sensor-element temperature control, which is based on determining the internal resistance of the Nernst cell, can also be implemented using a.c. voltage. In this case, the contact with the reference gas atmosphere is not necessary. Therefore, it is sufficient when only a part of the reference-electrode surface is directly exposed to the reference gas atmosphere. This allows the sensor design represented in Figure 3 to be simplified, as shown in Figure 4. Reference electrode 22 does continue to be led around measuring gas chamber 13 in a circular ring segment, but reference gas channel 15 does not.

In addition, the spatial dimensions of measuring electrode 21 are not restricted by the size of measuring gas chamber 13. Figure 5 depicts a sensor design that includes a measuring

electrode 21, whose dimensions extend beyond measuring gas chamber 13, and thus reduce the internal resistance of the Nernst cell. Two reference electrodes 22, 24 are also provided.

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An additional exemplary embodiment is represented in Figure 6. It is possible to combine inner pump electrode 20 and measuring electrode 21 into measuring electrode 21a. If this measuring electrode 21a is situated on the side of solid electrolyte layer 11a that faces the gas chambers, as is also the case with reference electrode 22, then one can dispense with inserting solid electrolyte layer 11c, and the sensor design is simplified further. By selecting an appropriately thick, solid electrolyte layer 11d, it is then possible to integrate heating element 40 into the sensor element in such a manner, that it is equidistant from the two large surfaces of the sensor element, and is therefore arranged symmetrically. This sharply reduces the mechanical stresses occurring during the heating phase, above all, at the edges of the sensor element.

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The sensor element according to the present invention and the method for manufacturing it are not limited to the specified, practical options for refinement, but rather further specific embodiments are conceivable, which contain one or more solid electrolyte layers produced, using a printing method.

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What is claimed is:

1. A sensor element for determining the concentration of gas components in gas mixtures, in particular for determining the oxygen concentration in exhaust gases of internal combustion engines, comprising at least one pump cell which pumps oxygen into or out of a measuring gas chamber, as well as at least one concentration cell which has at least one reference electrode essentially arranged in a reference gas channel, the reference electrode interacting with a measuring electrode, the measuring gas chamber and the reference gas channel essentially being situated in the same layer plane, and the reference gas channel allowing contact with a reference gas atmosphere, wherein a partition (12), whose base is a ceramic paste applied to an adjacent, solid electrolyte foil, is arranged between the measuring gas chamber (13) and the reference gas channel (15).
2. The sensor element as recited in Claim 1, wherein the geometry of the partition (12) is largely adapted to the reference-gas-side boundary of the measuring electrode (21) situated in the measuring gas chamber (13).
3. The sensor element as recited in Claim 1 and 2, wherein the measuring electrode (21) has an annular design and is largely formed in the measuring gas chamber (13); and the partition (12) constitutes a segment of a circular ring.
4. The sensor element as recited in at least one of Claims 1 through 3, wherein the reference electrode (22) has a boundary on the side of the measuring gas chamber, the boundary being largely adapted to the shape of the partition (12)

boundary on the side of the reference gas.

5. The sensor element as recited in at least one of the preceding claims,
wherein the surface of the reference electrode (22) is tapered in its dimensions, from the end (16) of the reference gas channel (15) on the side of the measuring gas chamber, in the direction of the end (18) of the reference gas channel on the side of the gas intake, in such a manner, that the center of mass of the electrode surface approaches the center point of the measuring electrode (21) as closely as possible.
6. The sensor element as recited in at least one of the preceding claims,
wherein at least a section of the reference gas channel (15) and/or of the reference electrode (22) is at least partially led around the measuring gas chamber (13).
7. The sensor element as recited in at least one of the preceding claims,
wherein an inner pump electrode (20) of the pump cell is arranged in the measuring gas chamber (13), oppositely to the measuring electrode (21).
8. The sensor element as recited in at least one of Claims 1 through 6,
wherein the measuring electrode (21) situated in the measuring gas chamber (13) simultaneously forms an inner pump electrode (20) of the pump cell.
9. The sensor element as recited in at least one of the preceding claims,
wherein the measuring gas chamber (13) has at least one opening (25) on the large surface of the sensor element facing the gas mixture, the opening being essentially normal to the upper surface of the sensor element, and

allowing the gas mixture to enter into the measuring gas chamber (13).

10. The sensor element as recited in at least one of the preceding claims,
wherein the measuring gas chamber (13) is designed to be circular, and the center point of the circle lies on the center line of the opening (25).
11. The sensor element as recited in Claim 10,
wherein the measuring electrode (21) and the inner pump electrode (20) are designed to be annular, and a diffusion barrier (27), which is annular as well, is arranged in front of them, in the diffusion direction of the gas mixture.
12. The sensor element as recited in one of the preceding claims,
wherein the reference electrode (22) is situated on the side of the reference gas channel (15) that points in the direction of the large surface of the sensor element exposed to the gas mixture atmosphere.
13. The sensor element as recited in at least one of the preceding claims,
wherein two diametrically opposed reference electrodes (22, 24) are situated in the reference gas channel (15).
14. The sensor element as recited in at least one of the preceding claims,
wherein a part of the measuring electrode (21) is situated outside of the measuring gas chamber (13).
15. The sensor element as recited in at least one of the preceding claims,
wherein a part of at least one of the reference electrodes (22, 24) is situated outside of the reference

gas channel (15).

16. The sensor element as recited in at least one of the preceding claims,
wherein the reference gas channel (15) is at least partially filled in with a porous ceramic material, which preferably corresponds to that of the diffusion barrier (27).
17. The sensor element as recited in at least one of the preceding claims,
wherein a first, solid electrolyte foil (11a) exposed to the gas mixture atmosphere, and a solid electrolyte layer (11b) containing the measuring and reference gas channels, are provided, and the solid electrolyte layer (11b) is directly deposited on the solid electrolyte foil (11a).
18. The sensor element as recited in Claim 17,
wherein the solid electrolyte layer (11b) is connected to a second, solid electrolyte foil (11c), and this is connected to an additional, solid electrolyte foil (11d); and a heating element (40) is introduced between the second and the additional, solid electrolyte foils; and the layer thickness of the additional, solid electrolyte foil (11d) is dimensioned in such a manner, that the heating element (40) is essentially equidistant from the two large surfaces of the sensor element (10).
19. A method for manufacturing a sensor element as recited in at least one of Claims 1 through 18,
wherein a solid electrolyte layer (11b) is applied to a solid electrolyte foil (11a) by screen-printing a pasty ceramic material, the solid electrolyte layer (11b) containing the measuring gas chamber (13) and the reference gas channel (15).

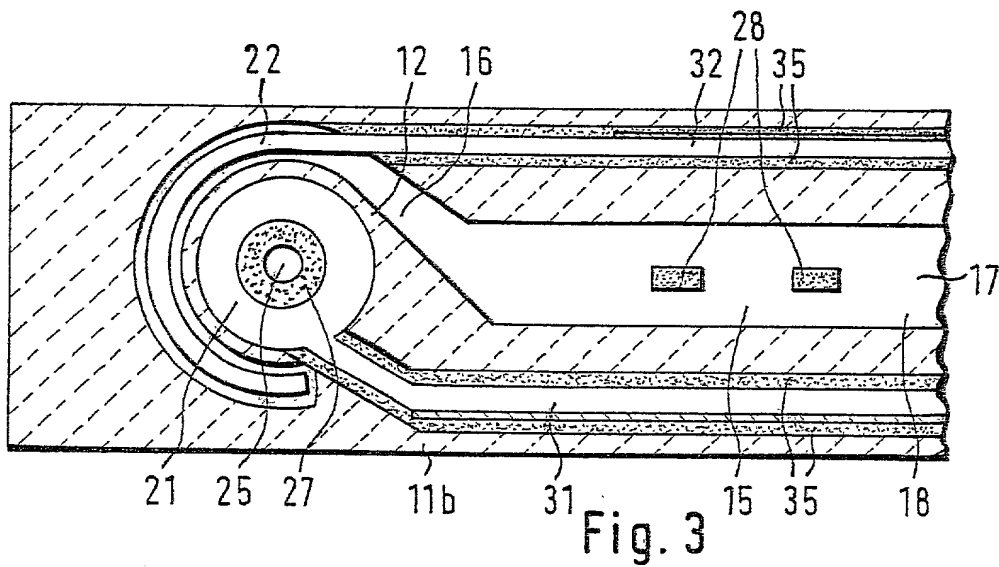
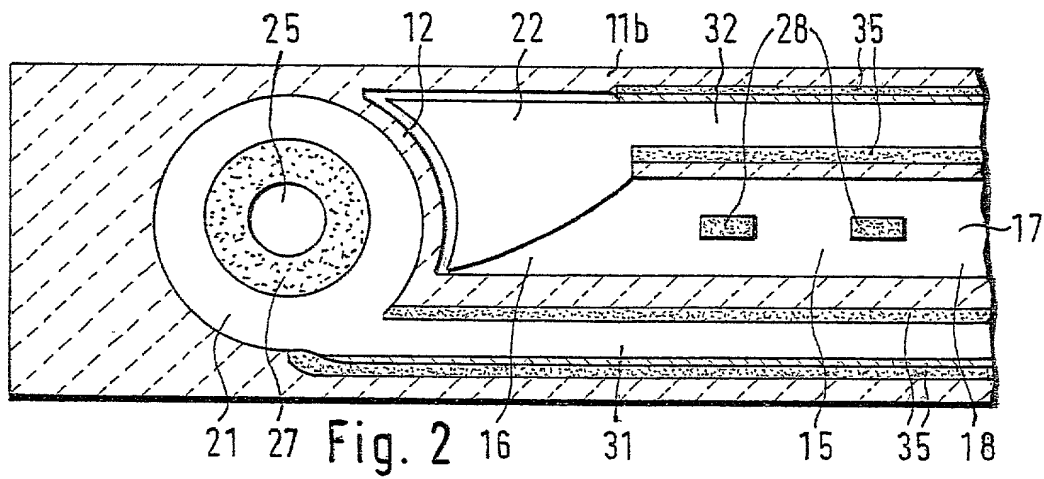
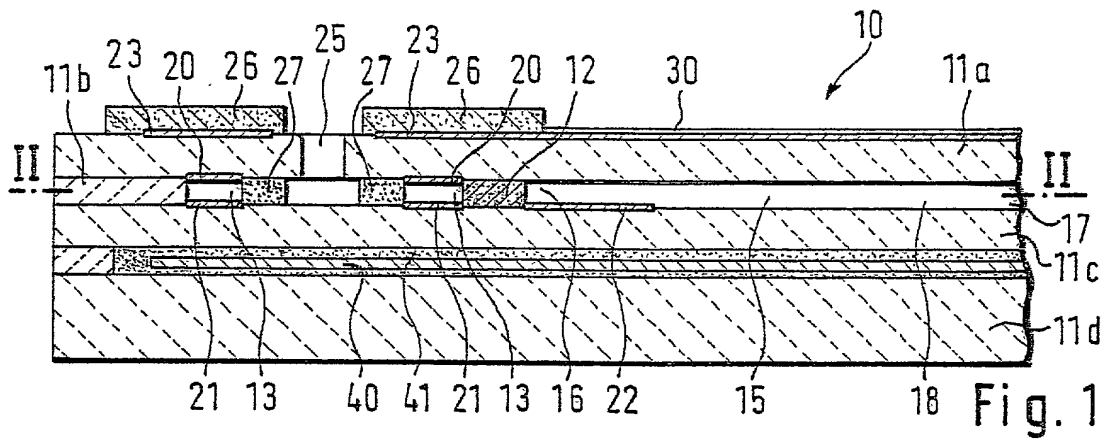
20. The method as recited in Claim 19,
wherein a boundary for the measuring gas chamber (13) and
the reference gas channel (15) is produced by the solid
electrolyte layer (11b).
21. The method as recited in Claims 19 and 20,
wherein at least one supporting element (28) is produced
in the reference gas channel (15), using the solid
electrolyte layer (11b).
22. The method as recited in Claims 19 through 21,
wherein the pasty ceramic material contains the same
solid electrolyte as the solid electrolyte foil (11a).
23. The method as recited in Claims 19 through 22,
wherein a thermal treatment, by means of which the pasty
ceramic material is converted into a ceramic form, is
carried out after the printing procedure.

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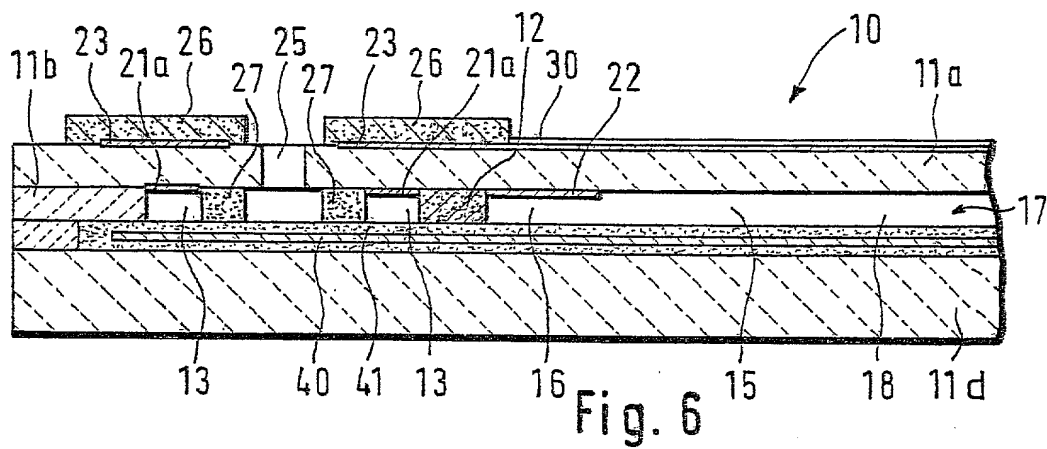
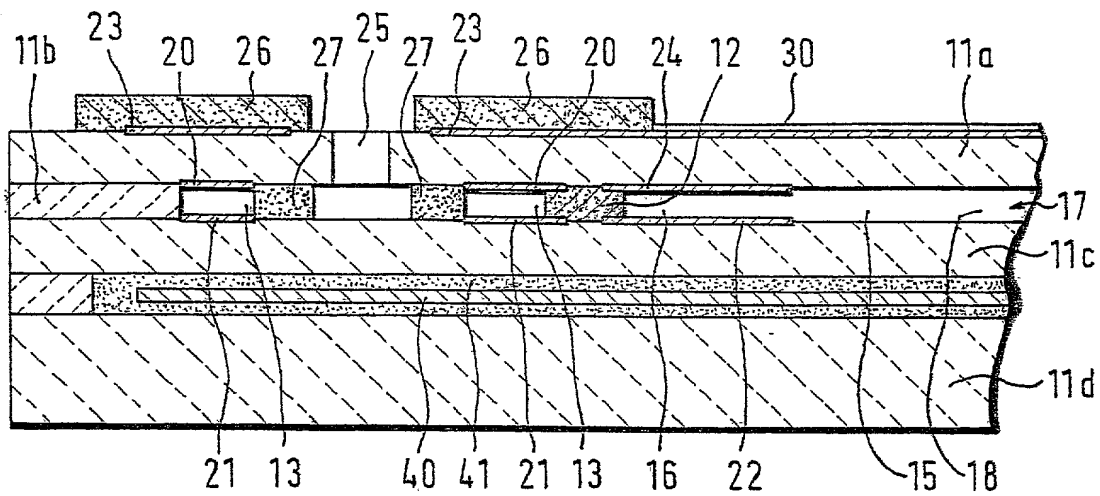
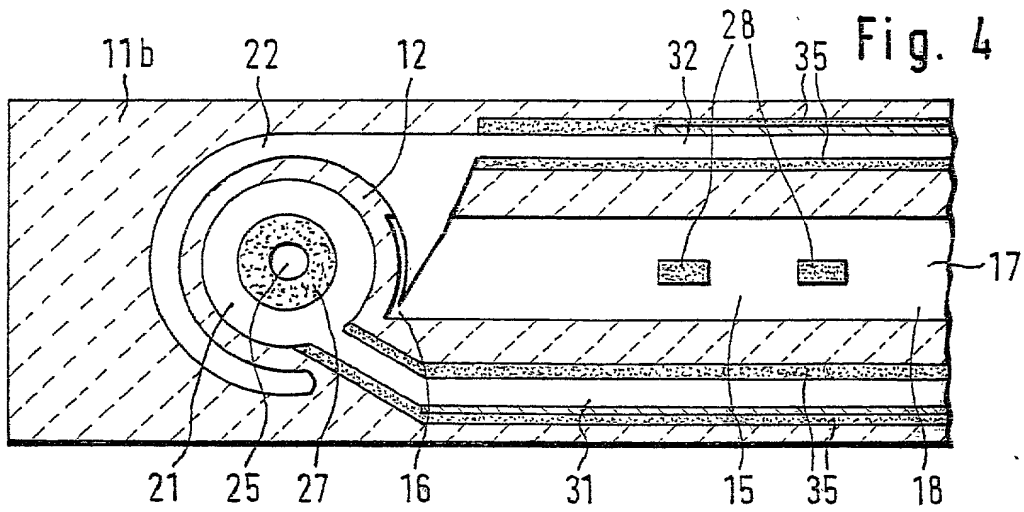
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DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **SENSOR ELEMENT FOR DETERMINING THE OXYGEN CONCENTRATION IN GAS MIXTURES AND METHOD FOR ITS MANUFACTURE**, the specification of which was filed as PCT International Application No. PCT/DE00/02879 on August 23, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

2L302704059

PRIOR FOREIGN APPLICATION(S)

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
199 41 051.8	Fed. Rep. of Germany	28 August 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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